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THE ACTUATOR, EXPLOSIVE WOX-23A, AN ACTUATOR TO REPLACE ACTUATOR MK 3 MOD 0 IN THE EXPLOSIVE SWITCH MK 46 MOD 0 (U)

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4 MAY 1960

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

THE ACTUATOR, EXPLOSIVE WOX-23A, AN ACTUATOR TO REPLACE ACTUATOR MK 3 MOD 0 IN THE EXPLOSIVE SWITCH MK 46 MOD 0

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ABSTRACT: In view of Explosive Switch Mk 46 Mod 0 failures, a program was initiated to find a suitable replacement for the Actuator Mk 3 Mod 0. An investigation indicated that the inability of the Olin-Mathieson Ball Powder (W2920.3 Type II class 4) to sustain burning under the leakage condition existing in the Mk 46 Mod 0 Switch to be the cause of the explosive switch failures. Various propellants were investigated both in a variable volume pressure bomb and in the Explosive Switch Mk 46 Mod 0. Of the powders tested, SR4990, a DuPont smokeless powder, gave the desired boundary condition of a fast rise pressure front unaffected by the change of volume in the switch. Consequently, a direct substitution replacing the Olin Mathieson Ball Powder (W2920.3 Type II class 4) by SR4990 (DuPont) will be made in the actuator for the switch Mk 46 Mod 0. The new actuator has been designated Actuator, Explosive, WOX-23A.

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WHITE OAK, MARYLAND

This report presents information concerning an investigation to find a suitable replacement for the Actuator Mk 3 Mod 0 as used in the Explosive Switch Mk 46 Mod 0. This work was accomplished by the Explosion Dynamics Division of the Explosions Research Department. It bears on key problem 11, Supporting Research for Antisubmarine Warfare, NavOrd Report 4299. The results of this investigation are intended for the information and use of the Naval Ordnance Laboratory and should be of interest to others working with explosive components and explosive switches.

W. D. COLEMAN

C. J. Aronson

C. J. ARONSON
By direction

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ILLUSTRATIONS

(cont'd.)

THE ACTUATOR, EXPLOSIVE WOX-23A, AN ACTUATOR TO REPLACE ACTUATOR MK 3 MOD 0 IN THE EXPLOSIVE SWITCH MK 46 MOD 0

INTRODUCTION

1. When the first production lot of Explosive Switches Mk 46 Mod 0, Lot K, was tested for switch functioning and delay time, 2/10 switch failures, switch leaks, and variable switch functioning times resulted. The Explosive Switch Mk 46 Mod 0, shown in Figure 1, operates from the gas pressure produced by the Explosive Actuator Mk 3, Figure 2. It was believed that the deficiencies noted were caused by leakage, from the switch, of the gases produced by the actuator. This corroborates information found in other work[1] which indicated poor performance because of extreme leakage.

In view of the switch failures with the Actuator Mk 3 Mod 0, a program was initiated to find a suitable replacement for the W2920.3 base charge in this actuator as used in the Switch Mk 46 Mod 0. This new powder ideally would be one which would reliably function in the switch under adverse conditions such as:

(a) Leakage of gas on actuator functioning

(b) Improperly seated pistons

(c) Variations in tolerances of switch parts.

In addition it was desired that the powder be covered by a military specification.

2. A survey was made of available propellant type powders that might be considered as replacements for the base charge in the Explosive Actuator Mk 3 Mod 0. Samples of several, as given below, were obtained for testing and comparison with Ball Powder W2920.3

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1 - NavOrd Report 6131: "Approval of Ball Powder Type WC-860 for Use in the Explosive Actuator Mk 4 Mod 0", by James H. Herd, August, 1958.

(a) W2920.3 (Olin Ball Powder)

(b) SR 4990 Smokeless Powder (DuPont)

(c) SR 4759 (DuPont)

(d) IMR 5010, Al 40320 (DuPont)

(e) IMR 5010, OKL 28754 (DuPont)

(f) Unique Powder (Hercules)

(g) Hi-Vel #2 (Hercules)

(h) FNH 24711 (Military 50 caliber powder)

(i) WC 860 (Military 50 caliber powder).

At that time, with the exception of W2920.3 and WC 860, there were no available data on the performance of these propellant type powders in volumes as small as those in the Explosive Switch Mk 46 Mod 0. Therefore, as a first step in the replacement program, tests were conducted on these powders in a pressure bomb containing volumes simulating those in the Explosive Switch Mk 46 Mod 0.

PRESSURE BOMB TESTS

3. A pressure bomb, Figure 3, was designed in which the internal volume could be varied in three discrete steps, 0.033, 0.028, and 0.022 cubic inches. The volume range was approximately that of the expansion chamber in the Explosive Switch Mk 46 Mod 0 before and after firing. This bomb was used to determine the pressure-time-volume relationships for the various powders for comparison with the pressure-time-volume relationship of W2920.3. From the results observed in the pressure bomb, it was hoped that the powders worthy of further consideration could be selected.

4. An engine-pressure transducer (Norwood Controls Model #102) was used to determine the pressure fluctuations in the pressure bomb. This transducer contains two resistive windings as two of the arms of a Wheatstone bridge. Pressure variations cause resistance changes in these two windings. The bridge arrangement was monitored by a Tektronix Oscilloscope, Model 531. The pressure-time curves were recorded

by a Polaroid-Land camera. The engine-pressure transducer was used because past experience with propellant powders has shown that this transducer would be unaffected by corrosive gases, that it had the desired electrical characteristics, and would facilitate the cleaning of the pressure bomb.

5. Pressure-time curves were obtained for each of the powders tested. Figures 4 through 9 are typical pressure-time curves showing the different burning characteristics for each powder. It was generally observed that

> Hi-Vel #2, W2920.3 (Olin Ball Powder); IMR 5010, OKL 28754; WC 860; and IMR 5010, Al 40320 (DuPont) showed an "ignition lag" time.
>
> Unique and SR 4990 powders showed fast pressure rise times. SR 4759, although it did not have appreciable ignition lag, did not have as fast a pressure rise as the Unique and SR 4990 powders.
>
> All the powders except FNH 24711 exhibited a uniform ignition in all volumes tested. FNH 24711 had "ignition lag" in the pressure-time curve when tested in the pressure bomb. As the volume was decreased the ignition lag time decreased as shown in Figure 9. Therefore, this powder would not be suitable for switch application when used as a base charge substitute in the Actuator Mk 3 Mod 0.

6. Peak pressure-volume plots were made from the pressure-time curves for the powders tested. These are shown in Figures 10 and 11. These plots, indicated that several of the powders were more volume sensitive than others. The most volume sensitive powders in the pressure bomb were SR 4759, FNH 24711 (Military 50 caliber powder) and IMR 5010, Al 40320 (DuPont) for which a small incremental change in volume resulted in a marked change in the peak pressure produced.

7. Based on the pressure-volume and pressure-time data, the powders which exhibited sharp pressure-rise time characteristics and relative insensitivity to volume changes, were chosen for testing in the Explosive Switch Mk 46 Mod 0. Two of the powders so chosen were SR 4990 and Unique Powder. A third powder (SR 4759 - DuPont) was chosen for further testing because of its sharp pressure-rise time, even though it was sensitive to volume changes. It was thought that the fast pressure-rise might be of greater importance than the volume sensitivity in effecting proper switch operation.

TESTING IN THE MODIFIED EXPLOSIVE SWITCH MK 46 MOD 0

8. The Explosive Switch Mk 46 Mod 0, as designed, is actuated by the Explosive Actuator, Mk 3 Mod 0. The base charge of the actuator was replaced in the present work by the three powders chosen from the pressure-volume study. These modified actuators containing SR 4990, SR 4759, and Unique Powder, along with the standard Explosive Actuator Mk 3 Mod 0, were then tested in the Explosive Switch Mk 46 Mod 0 Assembly. Table 1 lists the weight of base charge for each powder used and the functioning time of the switch containing actuators having these charge weights. The charge weights were selected from the pressure vs. volume curves shown in Figure 11 in comparison with the results for W2920.3 ball powder. Based on the functioning time of the switch, i.e., the time between the application of the electrical pulse to the actuator and the breaking of the contacts in the switch by the moving piston, the weights of the powders appear to give equivalent performance to the Olin Ball Powder base charge used in the Explosive Actuator Mk 3 Mod 0. The time was measured by a Berkeley Time Interval Meter, Model 5120 C, and was monitored by a Textronix Oscilloscope, Model 531. The test equipment arrangement is shown in Figure 12.

9. A poorly sealed switch which will allow gases to escape is a source of switch functioning failure. This is shown in Table 2 obtained from earlier tests with the Actuator Mk 3 Mod 0 tested in the Switch Mk 46 Mod 0. It was decided to build gas relief holes into a modified switch, as shown in Figure 13 and to ignite and test the selected base charge powders under these conditions. The results of these tests, Table 3, showed that actuators with SR 4759 and Unique Powder base charges were adversely affected by the venting of the gases from the expansion chamber. This was shown by the switch functioning time. To further test this result, actuators with reduced base charges were tested,with the results shown in Table 4. The data definitely show SR 4759 and Unique Powder to be sensitive to leaks while SR 4990 behaves equally well in the vented and unvented systems. Figures 14 and 15 show the radiographs of the modified expended switches. The switches actuated with SR 4990 functioned properly. The reduced movement of the pistons in the switches actuated by the other powders is clearly noticeable.

10. With the completion of this testing for the Explosive Switch Mk 46 Mod 0, it was decided to replace the base charge in the Actuator Mk 3 Mod 0 with SR 4990 smokeless powder. Switches containing modified actuators (25 mg. of SR 4990 base charge) were tested at -65° and 160°F. The results shown in Table 5 indicate a proper switch functioning over this temperature range.

ACTUATOR OUTPUT

11. The output acceptance criterion for the Actuator Mk 3 Mod 0 as used in the Explosive Switch Mk 46 Mod 0 was to test in actual switches for proper switch functioning. This test method was expensive. To reduce the cost of the output testing of the modified Actuator Mk 3 Mod 0, a switch simulator, Figure 16, was designed. The piston and the actuator are replaced in the switch simulator following each test. The fired actuator is pushed from the sleeve and the piston is removed from the switch on disassembly of the simulator. Several weights of SR 4990 base charge were tested in the simulator to determine the functioning times. From the results of these data, Table 6, a base charge weight of 25 to 30 milligrams of SR 4990 powder was indicated for use in the modified Explosive Actuator Mk 3 Mod 0.

12. The weight limit placed on the base charge of the actuator was $0.025 \begin{smallmatrix} +.005 \\ -.000 \end{smallmatrix}$ grams of SR 4990 powder. Actuators were loaded with the upper and lower charge limits and tested for functioning. The results, given in Table 7, show proper switch functioning at both weight extremes. This weight tolerance was chosen after consideration of the pressures "built up" in the switch, the functioning time, and the fabrication of a reliable actuator. The specification for the manufacture and testing of this actuator will contain these weight limits.

13. The switch signature was a secondary point of interest, but proved valuable as a check on the actuator output. A typical switch signature and the circuit for obtaining it, are shown in Figure 12. The switch contacts were monitored by the Tektronix Oscilloscope, Model 531, which picked up the change in voltage in the switch circuit and displayed it as a vertical deflection on the cathode ray tube. The oscilloscope face was photographed and recorded with a Polaroid-Land Camera. This record was informative in that not only was the switch functioning time obtained, but it served as an indication of the "sharpness" of switching

while the piston was being moved. The sharp clean break shown in Figure 12 is typical for the Explosive Switch Mk 46 Mod 0 with the new actuator.

CONCLUSIONS

14. From the testing and observed data the following conclusions can be drawn:

(a) The method of static testing in a pressure bomb using several volumes is appropriate for gaining insight into the characteristics of actuator base charges.

(b) The smokeless powder, SR 4990, is a suitable base charge for a modified Explosive Actuator Mk 3 Mod 0 of greater reliability in the Explosive Switch Mk 46 Mod 0.

(c) The Explosive Switch Mk 46 Mod 0 will function over the temperature range of -65°F to 160°F, using Mk 3 Mod 0 type actuators with the SR 4990 base charge.

(d) The Explosive Switch Mk 46 Mod 0 simulator is a suitable fixture for use in the quality control testing of Actuators, Mk 3 type.

Table 1

THE MK 46 MOD 0 EXPLOSIVE SWITCH FUNCTIONING TESTS

Mk 46 Mod 0 Explosive Switches
Functioning Time* (microseconds)

	SR 4759 (30 mg.)**	SR 4990 (25 mg.)**	W2920.3 (40 mg.)**	Unique (25 mg.)**
	277	205	242	242
	218	179	263	241
	236	194	251	214
	236	198	279	255
	265		308	202
$\bar{X}$	246	194	269	231
S	24	11	26	22

* All switches tested at room temperature with a firing pulse from a 6-microfarad capacitor charged to 80 volts.

** Base charge weight of smokeless powder.

Table 2

THE MK 46 MOD 0 EXPLOSIVE SWITCH FUNCTIONING TESTS USING LOT K, MK 3 MOD 0 ACTUATORS CONTAINING OLIN-MATHIESON BALL POWDER W2920.3

Functioning Time* (microseconds)	Remarks
372	switch leaked
switch failed to function	actuator fired, switch leaked
299	switch leaked
530	switch leaked
6,358	switch leaked
534	
271	switch leaked
7,518	switch leaked
410	switch leaked
switch failed to function	actuator fired, switch leaked

* All switches were fired at room temperature with a pulse from a 6-microfarad capacitor charged to 80 volts.

Table 3

THE MODIFIED (EXTERNALLY VENTED) MK 46 MOD 0
EXPLOSIVE SWITCH FUNCTIONING TESTS

	Functioning Time* (microseconds)		
	SR 4759 (30 mg.)**	SR 4990 (25 mg.)**	Unique (25 mg.)**
	304	217	1,669
	1,518	208	329
	2,547	217	259
	2,323	214	283
	304	210	376
	282	--	--
$\bar{X}$	1,213	213	583
S	1,060	4	608

* All switches tested at room temperature with a firing pulse from a 6-microfarad capacitor charged to 80 volts.

** Base charge weight of smokeless powder.

Table 4

THE MK 46 MOD 0 EXPLOSIVE SWITCH TESTED FOR FUNCTIONING WITH REDUCED BASE CHARGES

	Functioning Time* (microseconds)		
Type of Switch	SR 4759 (15 mg.)**	SR 4990 (15 mg.)**	Unique (15 mg.)**
Unmodified	297	222	274
"	238	208	282
"	292	218	270
"	298	224	265
"	353	219	245
Modified	458	262	switch did not function
"	switch did not function	278	"
"	"	277	"
"	"	292	"
"	"		"

* All switches were tested at room temperature with a firing pulse from a 6-microfarad capacitor charged to 80 volts. All actuators fired in the above tests.

** Base charge weight of powder.

Table 5

THE MK 46 MOD 0 EXPLOSIVE SWITCH FUNCTIONING TESTS OVER THE TEMPERATURE RANGE -65°F TO 160°F

	SR 4990 (25 mg.)** Functioning Time* (microseconds)	
	-65°	160°
	251	185
	188	148
	213	172
	197	159
	215	244
$\bar{X}$	213	182
S	24	38

* All switches fired with a pulse from a 6-microfarad capacitor charged to 80 volts.

** Base charge weight of powder.

Table 6

THE MK 46 MOD 0 EXPLOSIVE SWITCH SIMULATOR TESTS USING THE VARIOUS WEIGHTS OF BASE CHARGE IN THE MK 3 MOD 0 ACTUATOR

POWDER Base Charge Weight	Number Fired*	Mean Functioning Time (Microsec.)	Standard Deviation (microsec.)	Coefficient of Variation (%)
SR 4990 (30 mg.)	24	179	7.43	4.15
SR 4990 (25 mg.)	25	182	7.77	4.27
SR 4990 (15 mg.)	10	199	12.6	6.33

* All switches fired at room temperature with a pulse from a 6-microfarad capacitor charged to 80 volts.

Table 7

THE MK 46 MOD 0 EXPLOSIVE SWITCH FUNCTIONING TESTS
WITH LIMITED WEIGHTS OF BASE CHARGE

	Functioning Time* (microseconds)	
	SR 4990 (25 mg.)**	SR 4990 (30 mg.)**
	161	189
	180	175
	206	168
	167	198
	170	167
	185	169
	186	166
	188	170
	182	185
	169	171
$\bar{X}$	179	176
S	13	11

* All switches were fired at room temperature with a pulse from a 6-microfarad capacitor charged to 80 volts.

** Base charge weight of powder.

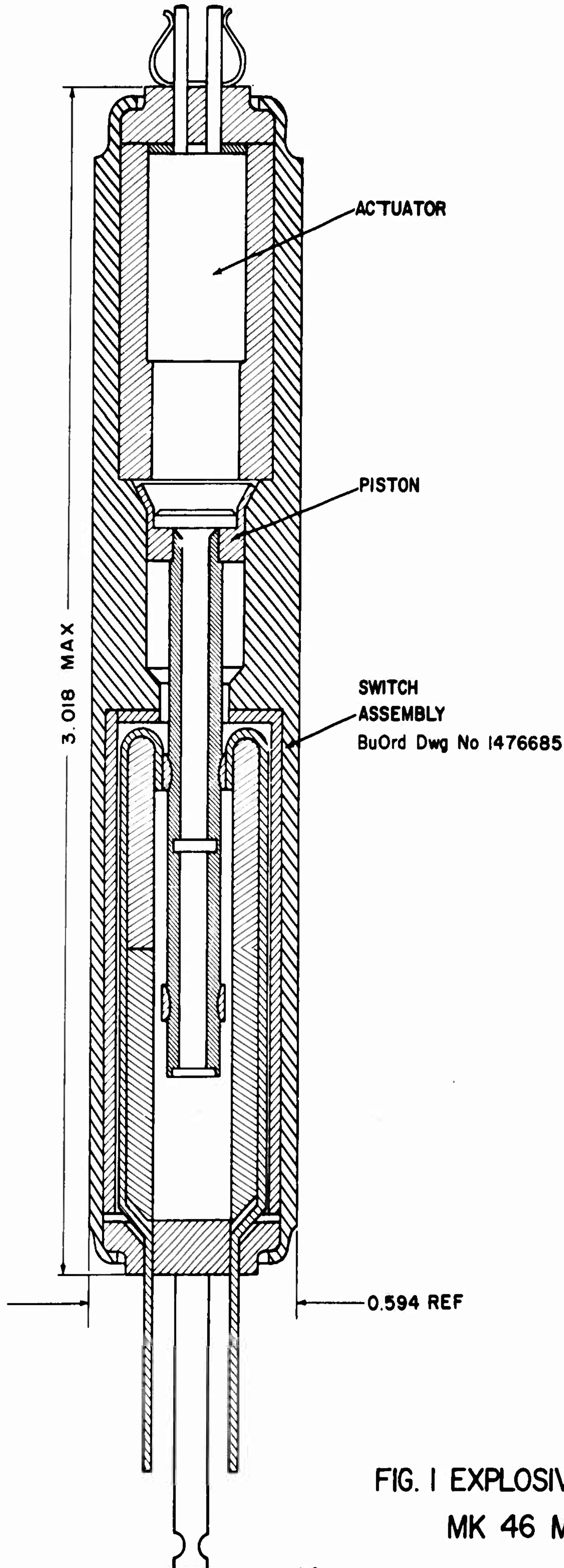


FIG. 1 EXPLOSIVE SWITCH
MK 46 MOD 0

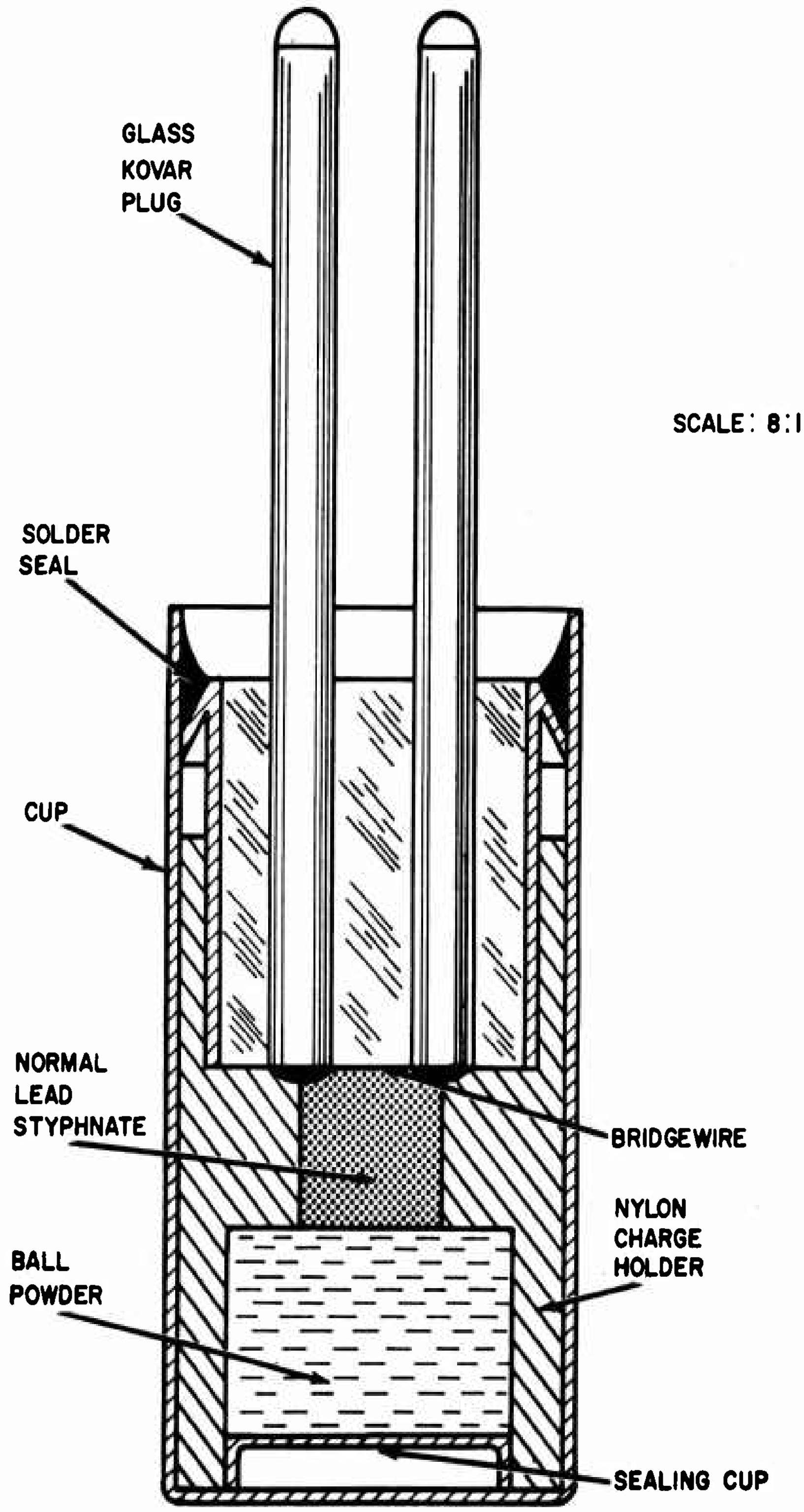
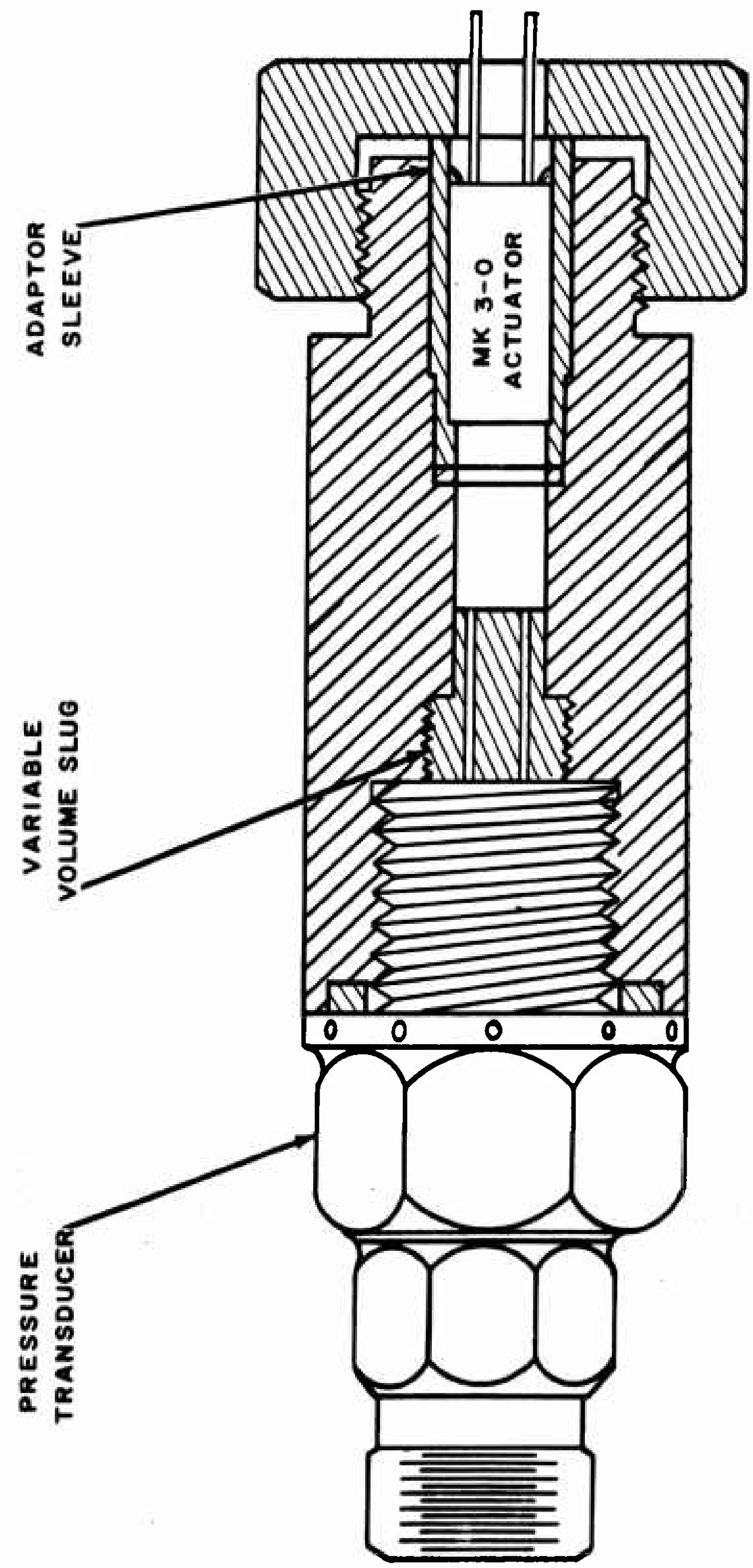
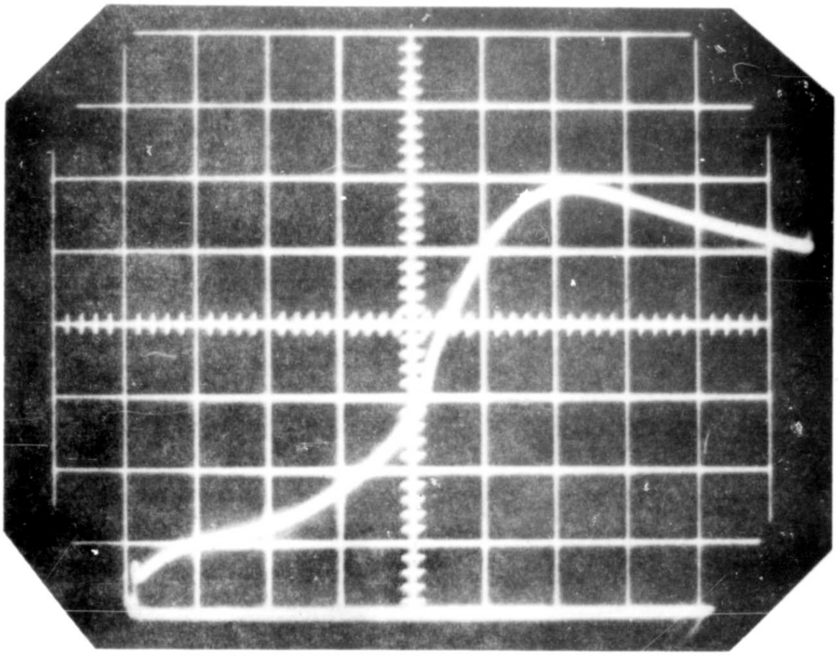


FIG. 2 EXPLOSIVE ACTUATOR MK 3 MOD O



SCALE 2:1

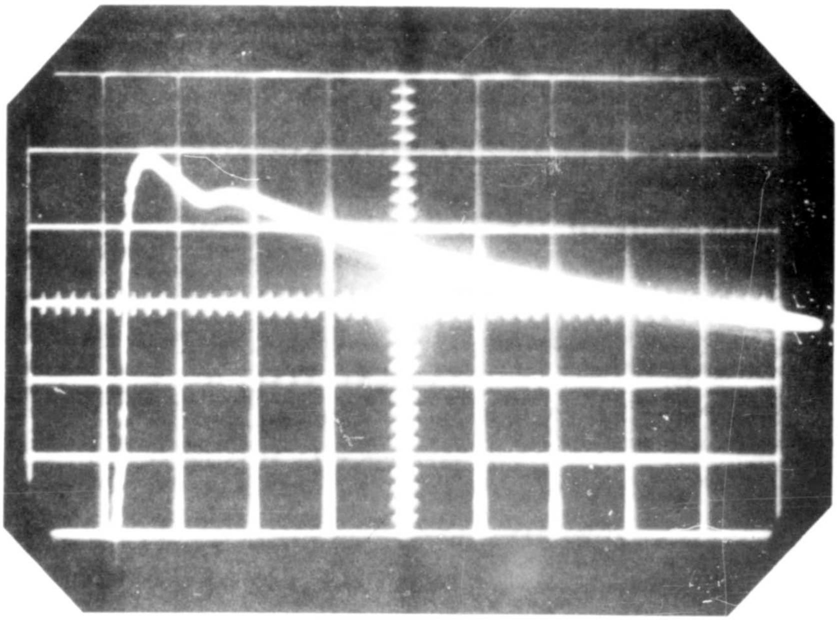
FIG. 3 THE PRESSURE BOMB ARRANGEMENT FOR TESTING VARIOUS BASE CHARGES



VERTICAL SENSITIVITY 1350 PSI/CM

SWEEP TIME 1 MS/CM

W 2920.3 (OLIN BALL POWDER) MK 3 MOD 0 ACTUATOR BASE CHARGE

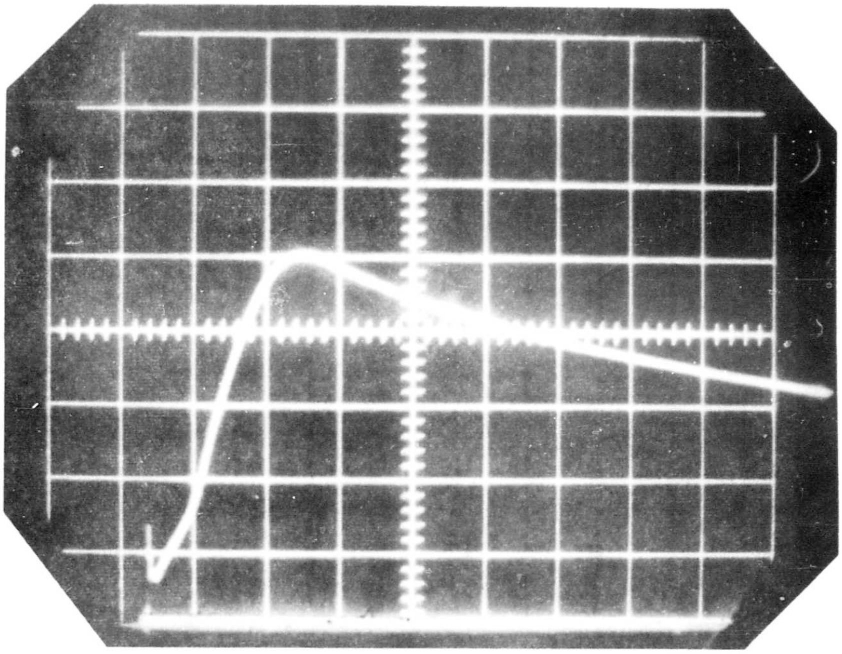


VERTICAL SENSITIVITY 1900 PSI/CM

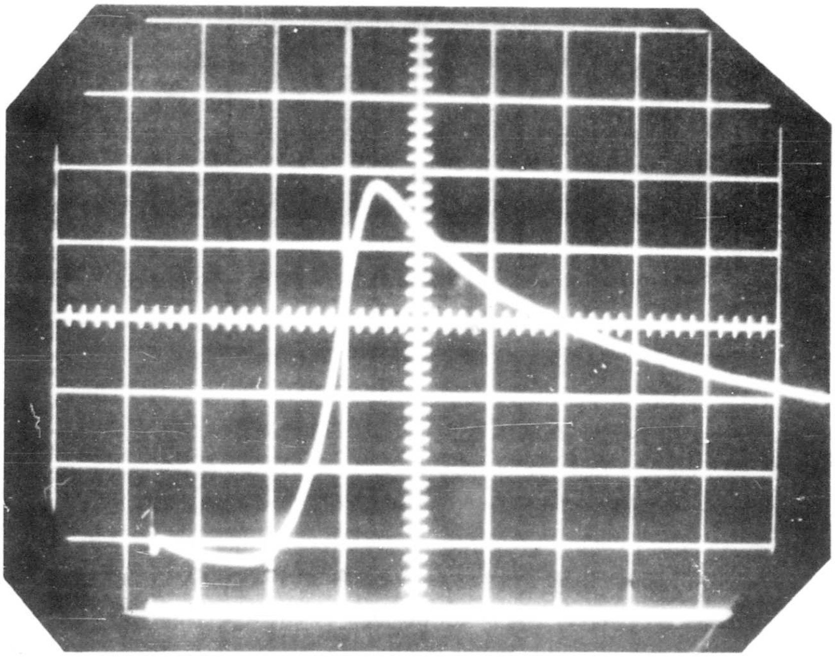
SWEEP TIME 1 MS/CM

SR 4990 SMOKELESS POWDER (DUPONT) WOX 23A ACTUATOR BASE CHARGE

FIG. 4 THE TYPICAL PRESSURE-TIME CURVES FOR W 2920.3 AND SR 4990 POWDERS



SR 4759 POWDER (DU PONT)

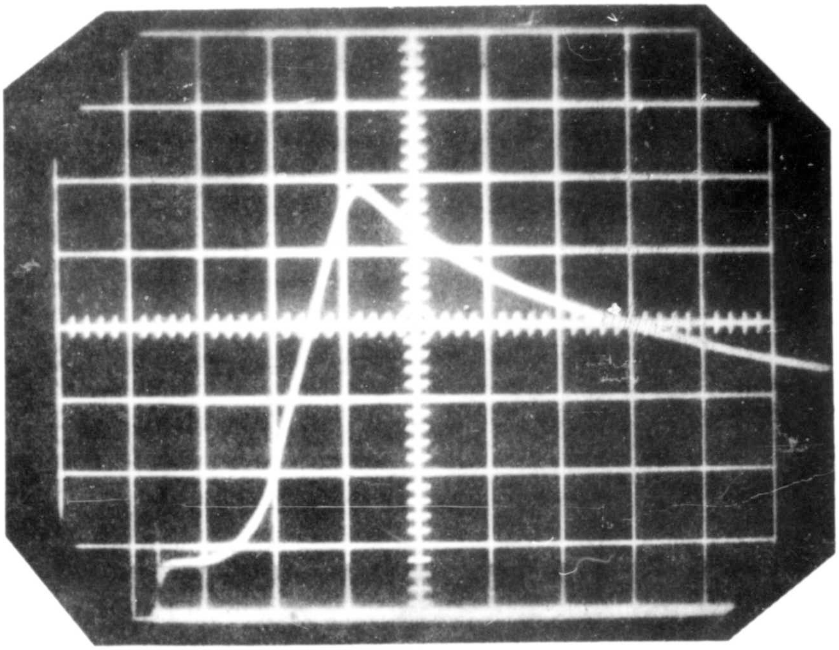


VERTICAL SENSITIVITY 1350 PSI/CM

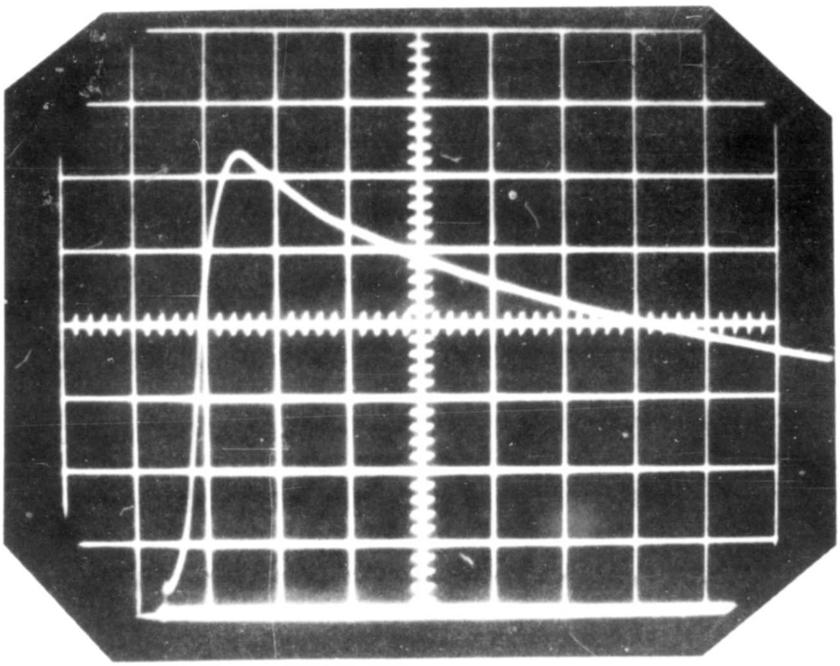
SWEEP TIME 1 MS/CM

IMR 5010 (AL40320) POWDER (DU PONT)

FIG.5 THE TYPICAL PRESSURE-TIME CURVES FOR SR 4759 AND IMR 5010 (AL40320) POWDERS



IMR 5010 (OKL 28754) DuPont

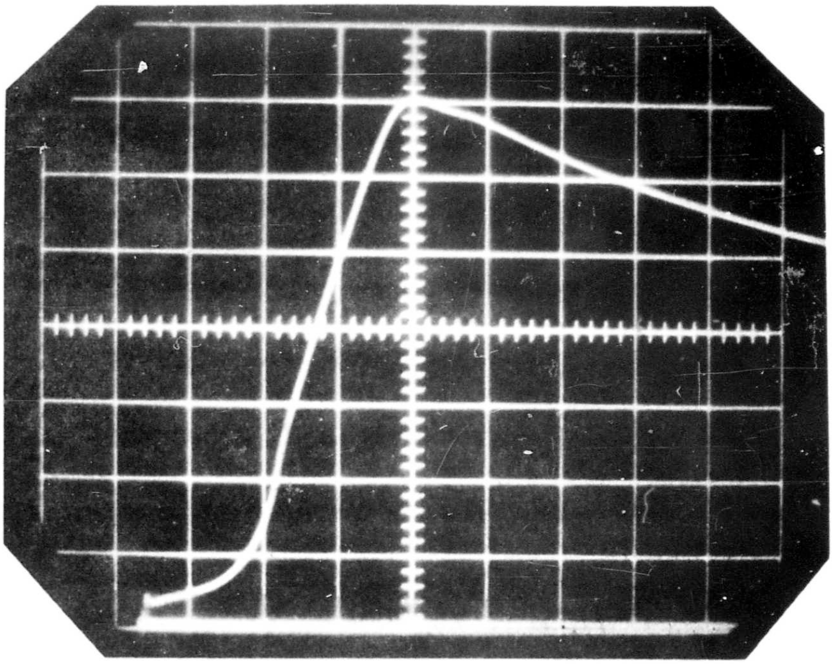


VERTICAL SENSITIVITY 1350 PSI/CM

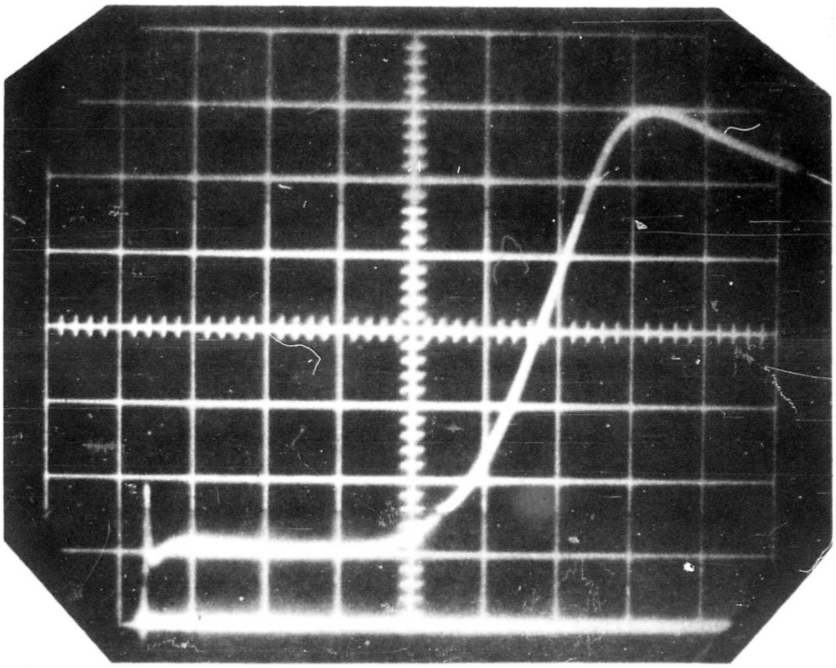
SWEEP TIME 1 MS/CM

UNIQUE POWDER (HERCULES)

FIG. 6 THE TYPICAL PRESSURE-TIME CURVES FOR IMR 5010 (OKL 28754) AND UNIQUE POWDERS



HI-VEL #2 (HERCULES)

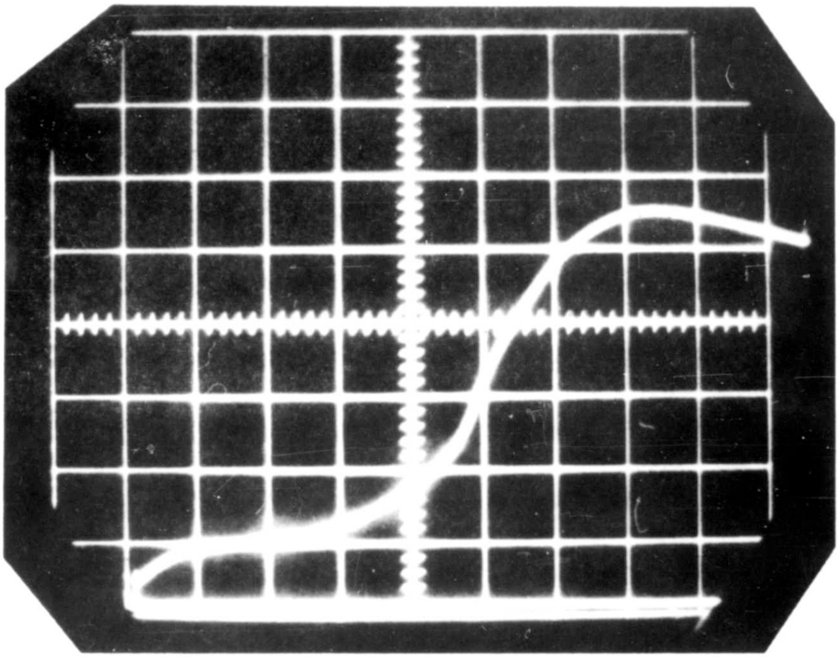


FNH 24711 POWDER

VERTICAL
SENSITIVITY
1350 PSI/CM

SWEEP
TIME
1 MS/CM

FIG. 7 THE TYPICAL PRESSURE-TIME CURVES FOR HI-VEL #2 AND FNH 24711 POWDERS

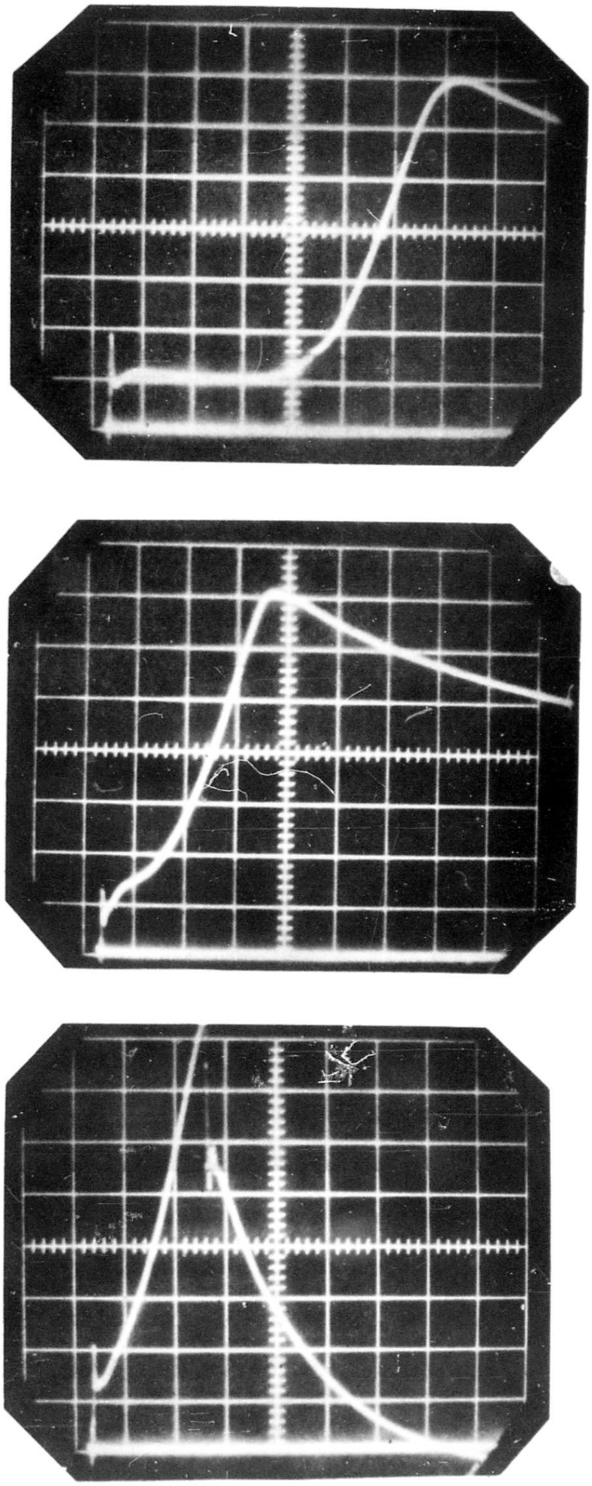


VERTICAL SENSITIVITY 1350 PSI/CM

SWEEP TIME 1 MS/CM

W C 860 BALL POWDER

FIG. 8 THE TYPICAL PRESSURE-TIME CURVE FOR WC 860 BALL POWDER



VERTICAL SENSITIVITY 1350 PSI/CM

SWEEP TIME 1 MS/CM

FIG. 9 THE TYPICAL PRESSURE-TIME CURVES FNH 24711 POWDER IN 0.033, 0.028 AND 0.022 CUBIC INCHES VOLUME

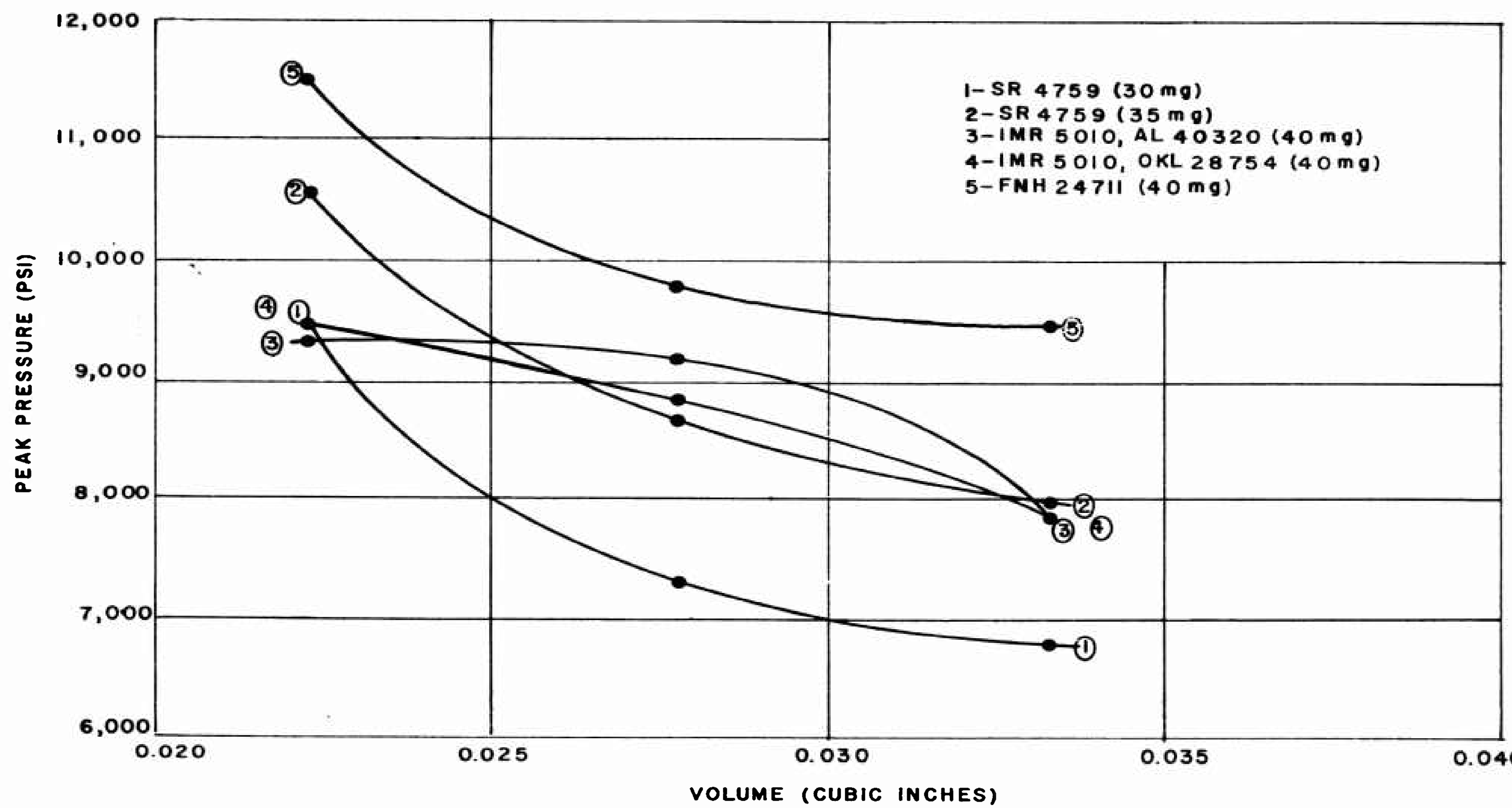


FIG. 10 THE PEAK PRESSURES OF VARIOUS BASE CHARGES AS A FUNCTION OF THE VOLUME OF THE PRESSURE BOMB

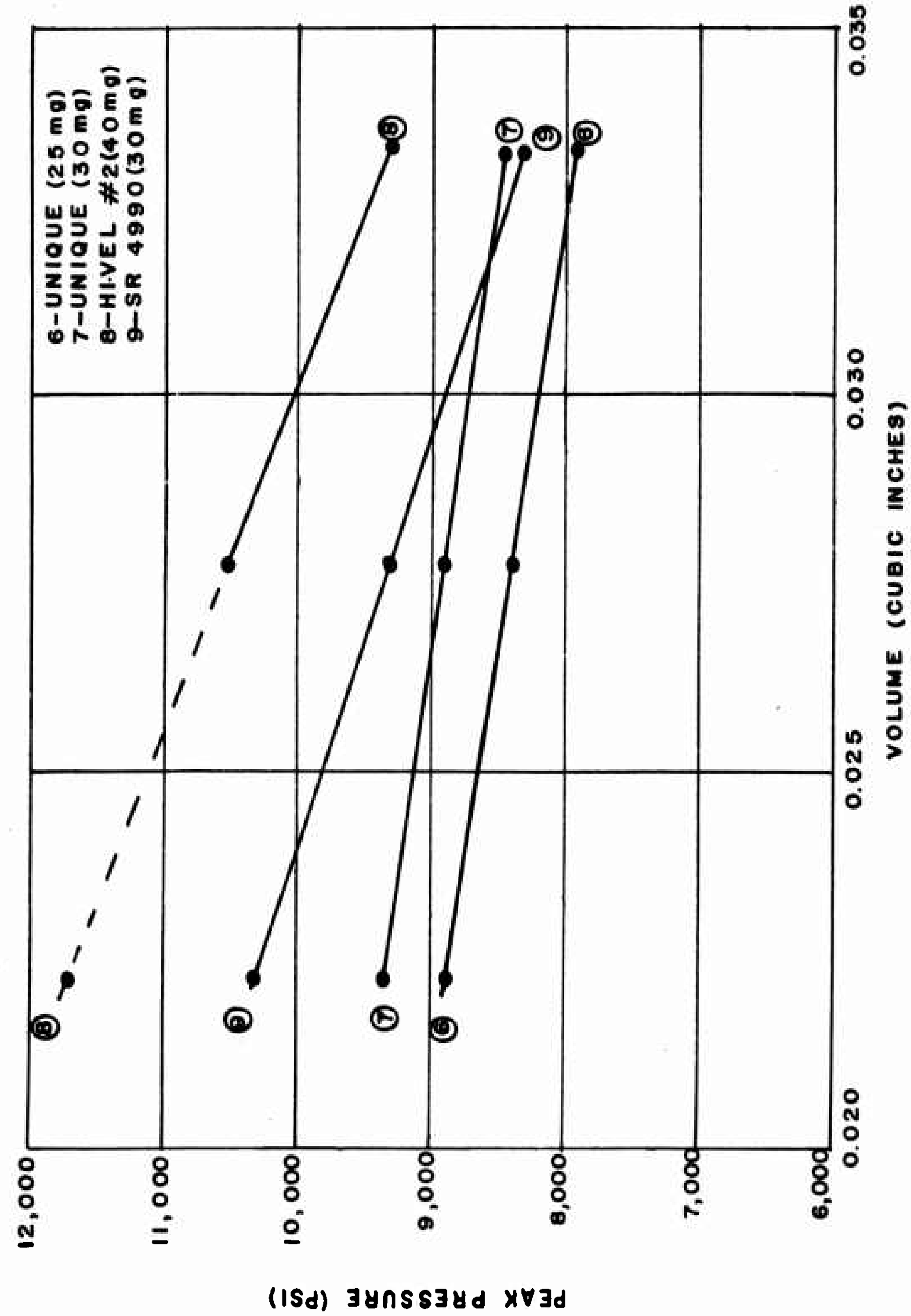


FIG. II THE PEAK PRESSURES OF VARIOUS BASE CHARGES AS A FUNCTION OF THE VOLUME OF THE PRESSURE BOMB

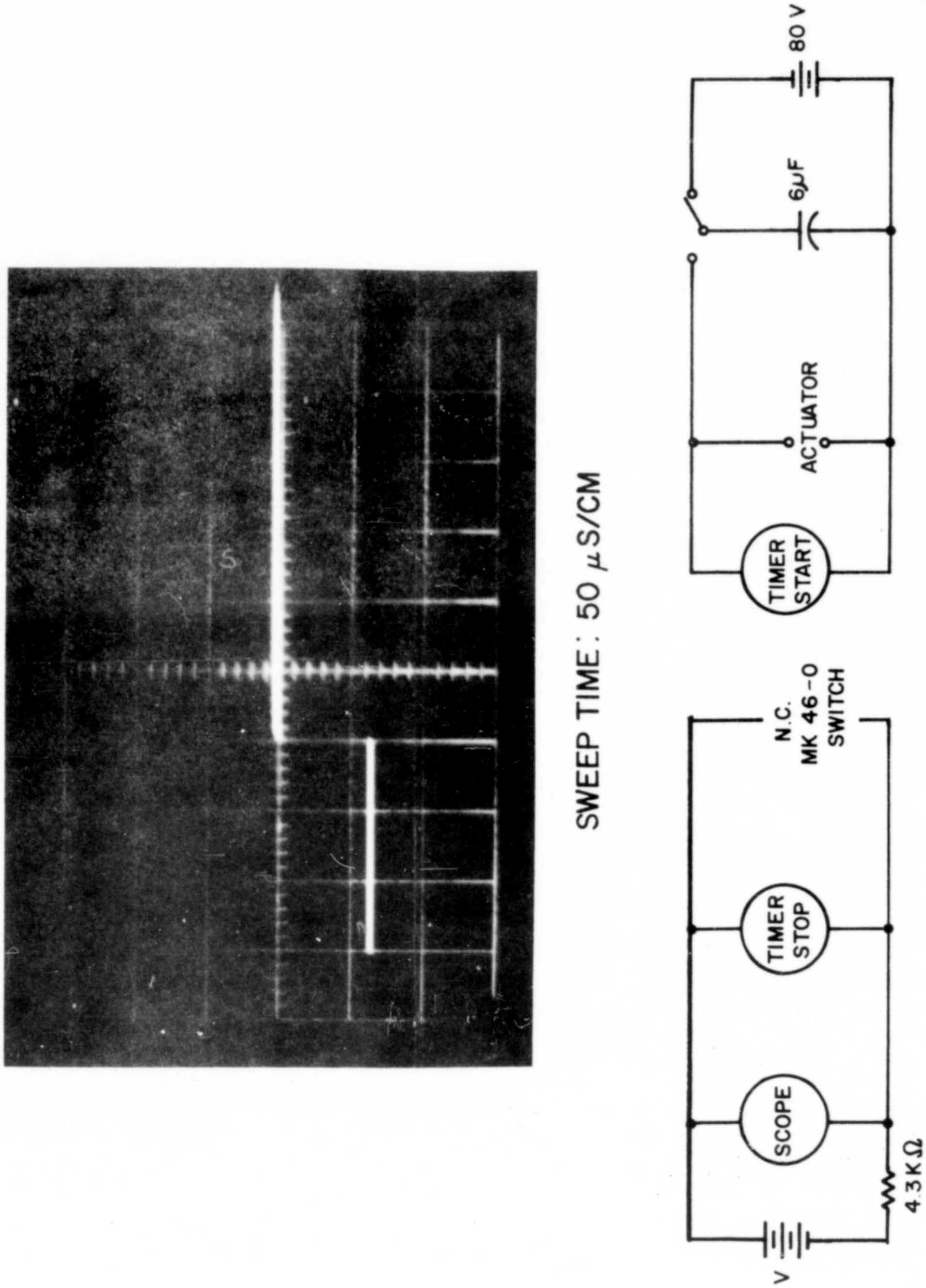


FIG. 12 A TYPICAL MK 46 SWITCH SIGNATURE AND THE SCHEMATIC USED TO OBTAIN IT

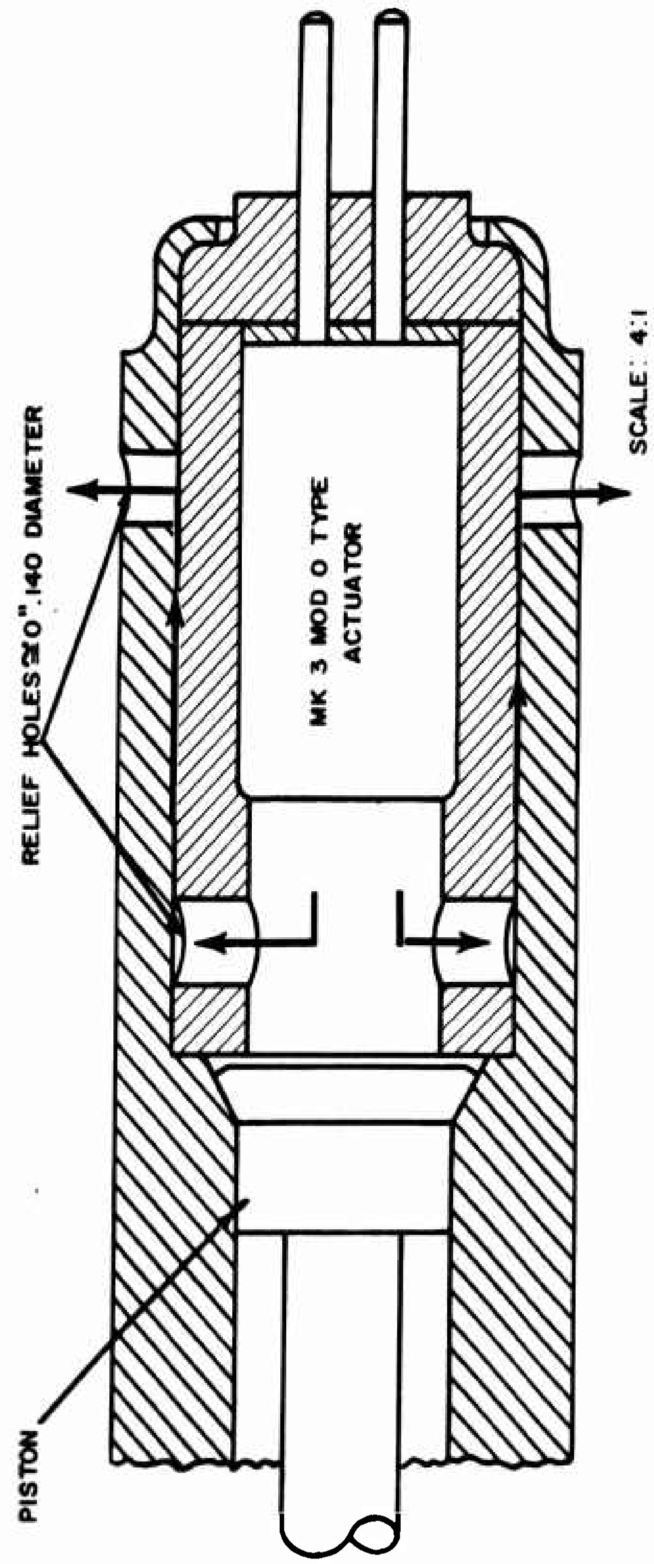
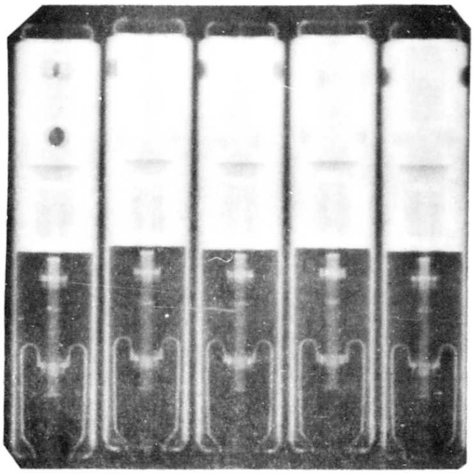
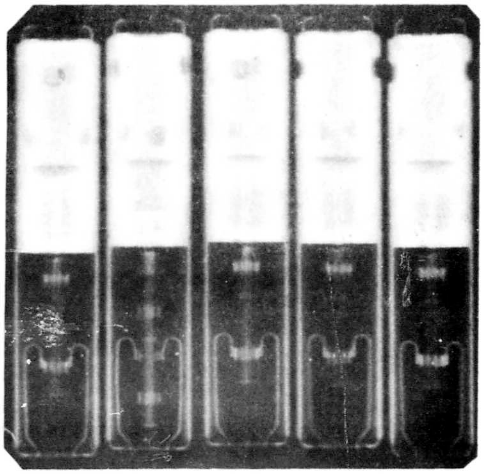


FIG. 13 THE MK 46 MOD O EXPLOSIVE SWITCH
MODIFIED FOR FUNCTIONING WITH VENTING



UNIQUE POWDER



SR 4759 POWDER

SR 4990 POWDER

FIG. 14 THE X-RAYS OF THE EXPLOSIVE SWITCH MK 46 MOD 0 FOLLOWING FUNCTIONING OF ACTUATORS WITH REDUCED BASE CHARGE

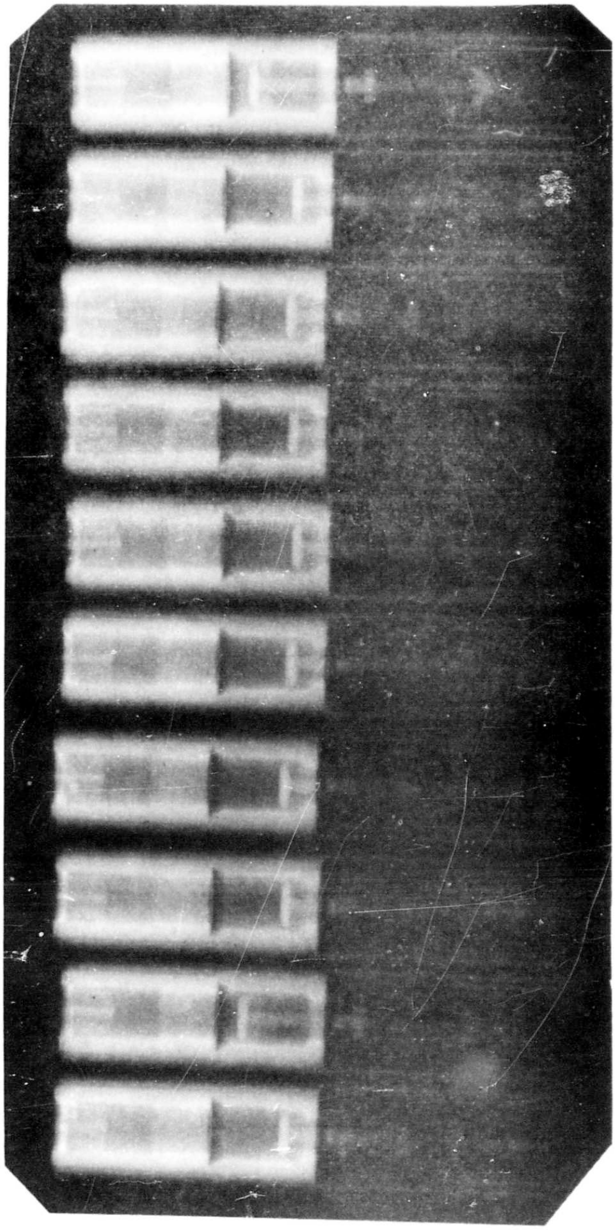


FIG.15 THE X-RAY OF THE EXPLOSIVE SWITCH MK 46 MOD 0 FOLLOWING FUNCTIONING WITH LOT K OLIN BALL POWDER

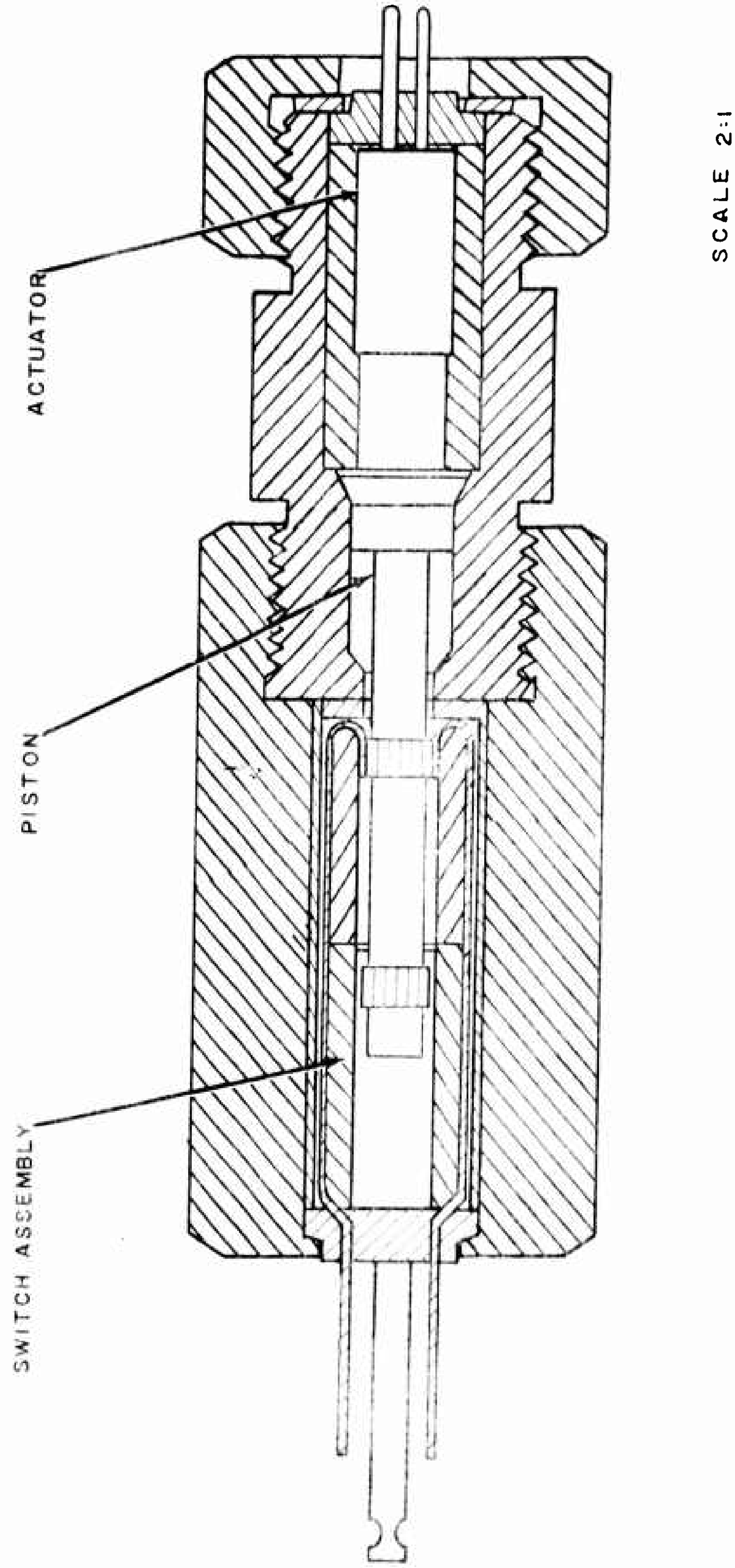


FIG. 16 THE MK 46 MOD 0 EXPLOSIVE SWITCH SIMULATOR (BU ORD L.D. 496529)

UNCLASSIFIED

UNCLASSIFIED